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May 3, 2000

Subject: Scope of Work for the California Offset Project

To Whom It May Concern:

Pursuant to the requirements of the Consent Decree filed in *United States v. Mack Trucks, Inc.* Case No. 98-1495 and pursuant to the Settlement Agreement between the California Air Resources Board and Mack Trucks, Inc., Mack Trucks, Inc. hereby submits our Scope of Work for the California Offset Project required by Paragraph 91 of the Consent Decree.

Mack Trucks, Inc. is not exercising any Confidential Business Information with regard to this submission.

To the best of my knowledge, after thorough investigation, I certify that the information contained in or accompanying this submission is true, accurate, and complete. I am aware that there are significant penalties for knowingly submitting false information, including the possibility of fines and imprisonment for knowing violations.

Glenn O. Shetter

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On Behalf of Mack Trucks, Inc.

Enclosures:

OVERVIEW

There are four distinct phases to the overall California Offset Project. Phases I-IV are identified as follows:

Phase I - The development of the Mack E7G-325 engine and calibration to produce emission levels of less than 2.5 gm/hp hr of NOx + NMHC and less than 0.05 PM. It also includes the placement of 3-5 refuse trucks with this engine in California.

Phase II - The development of the Mack E7G engine to provide 400 hp (E7G-400) with emission levels that meet the October 2002 diesel limits or below for NOx + NMHC and 0.05 Pm. This phase also entails the placement of 3-5 line haul tractors with this engine in California.

Phase III - The development of the Mack E7G-400 engine and calibration to produce emission levels of less than 2.0 gm/hp hr of NOx + NMHC and less than 0.05 Pm. It also includes the placement of 3 additional line haul tractors with this engine in California.

Phase IV - Further development of the efficiency of the Mack E7G-400 engine and calibration to produce efficiencies closer to a 2002 diesel engine but with the same low emission levels as in Phase III.

For the above projects, the following guidelines will be used:

- All emission testing is with California Air Resource Board (ARB) certification fuel.
- The emission levels stated in Phase I will be in accordance with the current FTP test procedures for spark ignited, throttled, natural gas fueled, heavy duty engines.
- The emission levels stated in Phases II, III and IV will be in accordance with the revised test procedures as stated in the August 1999 Consent Decree Amendment for spark ignited, throttled, natural gas fueled, heavy duty engines.
- The placement and operating service of the vehicles are to be in areas of California with high pollution levels and will likely all be in the South Coast area.
- It is understood that the engines and vehicles developed and tested through these phases are to become commercially available. It also needs to be understood that if a technology that is tested does not meet Mack's normal level of expected reliability & durability for a natural gas product that Mack has the right not to commercially offer that technology in order to protect the reputations of its customers, Mack Trucks and the natural gas industry as a whole.

SCOPE OF WORK

Phase I

There are two main tasks that will be focused on in this phase; certifying the E7G-325 at the reduced engine emissions and deploying 3-5 refuse trucks in California. Mack only has control over when we send in the request for engine certification and when we deliver trucks. The trucks, once delivered, may take months to get into service since the body must be available and installed. Therefore, these will be our two key deliverables in this phase as well as the other three phases.

Engine development will concentrate heavily on the transient operating condition to reduce the NOx and allow the engine to meet the 2.5 NOx + NMHC requirement. Natural gas engines have an inherently slower response time from idle to rated torque than a diesel engine does. This is due to the very slow speed of the turbo on a throttled natural gas engine at idle speed compared to the higher turbo speed of an unthrottled diesel engine at idle. Mack has demonstrated in the test cell at SwRI under the "Efficiency Enhancement Program" a new technology that uses air-assist to speed up the turbo quickly. The implementation of this idea will be one of the ways that are currently planned to help reach the project's requirements.

The vehicle deployment of 3-5 refuse trucks will proceed in parallel with the engine development. The vehicle will be based on the currently available natural gas refuse truck and then modifications, if required, will be added. The specific trucks though cannot be built or even planned to be built until one of the current potential customers actually places an order. Each company has its own truck configuration and it is impossible to build something generic. Two likely candidates are Waste Management and BURRTEC Waste. However, at this time neither one has placed a firm order with Mack. This is not crucial as of yet though since there is a seven month order backlog and the trucks should be built no sooner than 2 months after the engine certification application is submitted to allow for the new parts to be procured and the engines built. It would also be best to build one truck first and deliver it to the customer to ensure that it meets their expectations and specifications upon which the remainder will then be built and shipped.

Schedule for Phase I deliverables:

Apply for engine certification 12 months after approval of Scope of Work.
Deliver first refuse truck 14 months after approval of Scope of Work.
Deliver remaining 2-4 refuse trucks 16 months after approval of Scope of Work.

Phase II

This phase is the nucleus of the project. As in Phase I there are two main deliverables; an engine certification application for an E7G-400 at or below the diesel 2002 standards but with 0.05 PM limit and deployment of 3-5 line haul tractors in California. This phase is a major project for both the engine and the vehicle.

The engine will be based upon the E7G-325 engine. The power along with the peak torque will be raised to reach the 400 hp requirement. The exact torque curve will depend on the final turbocharger match but the preliminary peak torque should be in the area of 1440 ft. lb. Some of the required changes will be the fuel metering valve assembly so more fuel can be delivered to the engine, turbocharger matching, air-assist turbocharger work, new engine designs and possibly castings to accommodate the different vehicle it will be going into. Development work will be done to improve the Mack Dynatard engine brake performance. Additionally there will be a large amount of time spent in the transient emission cell so the calibration can be optimized to the new diesel-like emission test procedure. Because of the large number of new parts, the potential for new castings, and the new engine production line assembly and test procedures, more time is required between engine certification and the build of the first tractor to allow for new part procurement time and manufacturing implementation.

In addition to SwRI, Mack will also contract with Woodward Governor Company to help in the calibration and metering valve development. Woodward will also need to change their software in the natural gas engine electronic control module (EECU) so it can communicate with the vehicle electronic control unit (VECU), update the diagnostic software, and implement changes to comply with the Consent Decree. The current natural gas refuse truck by Mack uses only the stand alone Woodward EECU so this will be a major new task by Woodward. As previously mentioned Mack Trucks has signed a contract with GRI, SCAQMD and DOE to help leverage additional funding for the 400 hp engine development work.

This phase of the project is the only phase that heavily impacts Mack's Vehicle Engineering Group. The chassis of choice will be the newest version of the Mack CH (Conventional Highway) with a day cab (no sleeper). A sleeper version could be made available depending on the customer's requirements. The tractor will utilize Mack's latest VECU, the Vmac III, so the tractor will have all or most all of the electronic capabilities that the latest diesel tractors offer. Also the Snyder low pressure LNG fuel system will be evaluated for potential use which could help maximize the onboard fuel storage capacity. It is felt that this overall combination of high power and torque, full electronics, integrated engine brake and being alternatively fueled should provide good acceptance in the market place.

As is the case in Phase I, Mack does not have a definitive customer at this time. The best potential customer currently is Ryder Trucks who would then lease the tractors to ACE Hardware. Mack has presented to them this opportunity with good response. But again no firm orders have been placed. Other potential customers include the grocery store chains and the Post Office. One of the main obstacles for Mack, which is also an opportunity, is that in California Mack has very low market share and is thought of as an "East Coast" company. Although Mack's highest market share is certainly in the East, Mack has strengthened its West Coast sales

& service network immensely during the past two years. But still, many of the potential customers do not have any Macks and to bring five trucks into their fleet has many logistical issues that must be overcome.

Schedule for Phase II deliverables:

Apply for engine certification 18 months after approval of Scope of Work.
Deliver first tractor 24 months after approval of Scope of Work.
Deliver remaining 2-4 tractors 27 months after approval of Scope of Work.

Phase III

Phase III of the project is essentially the next evolution of the engine and vehicle developed in Phase II. For this reason the serious development work for the Phase III engine does not start until the Phase II engine has completed certification testing.

One of the major new technologies that will be introduced will be the late intake valve closing (LIVC) concept. The LIVC technology is still in its infancy but it has shown very positive results thus far. By keeping the intake valves open during part of the compression stroke, less volume of air is trapped in the cylinder. For equal power then, the air must become denser and to achieve this the throttle is opened more, raising the pressure in the inlet manifold. The more open throttle increases the engine's efficiency while the LIVC also reduces the NOx being generated. Although the hardware to selectively turn the LIVC on and off has been tested, the task of actually putting it into production faces many challenges. Either as a back-up or as an alternative a catalyst could be used to help reduce the emission levels. Additionally engine modeling will be conducted by SwRI to possibly find better optimization of the LIVC cam shape for a highway application and possibly to improve the efficiency versus NOx tradeoff of the piston design and compression ratio.

An additional control feature shall also be tested. An NOx sensor may replace the current oxygen sensor in the exhaust pipe. The NOx sensor provides an oxygen concentration output as well as a NOx concentration output. The engine would still be controlled primarily off of A/F ratio but then the ignition timing could be adjusted to dial the engine in to a predetermined NOx level. The control system would likely then consist of an additional look-up map with the desired NOx versus the speed and load (MAP) conditions.

The vehicle is not expected to require any major design changes at this time. The biggest change may be having to use a catalytic muffler if it turns out that a catalyst be required.

Schedule for Phase III deliverables:

Apply for engine certification 36 months after approval of Scope of Work.
Deliver 3 tractors 39 months after approval of Scope of Work.

Phase IV

Phase IV calls for the E7G-400 engine to remain at or below the emission requirements stated in Phase III but with increased efficiency so the gas engine is more like the diesel. This phase is the least defined phase due to the unknown technologies required and at what level of efficiency the gas engine will be at by the end of Phase III. Additionally the fuel efficiency of the diesel engine for year 2002 and beyond is not known. Therefore, this phase will be very general in description at this time. As Mack progresses with the next phases of the "Efficiency Enhancement Program" and the competing technologies are evaluated, a more definite direction can be identified.

As in Phase III, this phase will pick up where the last phase ended so the majority of the engine development work will not start until 36 months after the start of the project. One technology that will certainly be evaluated is turbo-compounding, the addition of a second turbine coupled back to the gear train. Next year one will be tested on a E7G engine at SwRI and based on these results we can determine if it will be worth pursuing further. Since more energy is lost in the exhaust stream on a gas engine versus a diesel engine (lower compression ratio), there is a good potential for higher efficiency gains when turbo-compounding is added to a spark ignited gas engine versus a diesel engine.

Other technologies which may be used are; high pressure gas injection, miller cycle, further ignition improvements and lean NOx catalyst.

Schedule for Phase IV deliverables:

Apply for engine certification or submit report to ARB 60 months after approval of Scope of Work.

Training

Mack and Woodward Governor Co. will conduct training at the local Mack dealerships that will support the customer site. A supply of natural gas service parts will be kept either at the dealer or on site in case of a part failure.

Data Tracking

It is planned that the Phase I and Phase II projects will be monitored for one year each and reported on. Mack will work with an outside contractor to perform this. Negotiations are currently underway with Gary Pope of USA Pro to perform this task. Mr. Pope lives in Southern California and has a very strong natural gas background which when combined provide excellent logistics for this project.

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May 23, 2000

Subject: Scope of Work for Mack Trucks, Inc. Environmental Projects

To Whom It May Concern:

Pursuant to the requirements of the Consent Decree filed in *United States v. Mack Trucks, Inc.* Case No. 98-1495 and pursuant to the Settlement Agreement between the California Air Resources Board and Mack Trucks, Inc., Mack Trucks, Inc. hereby submits our Scope of Work for all of our Environmental Projects (except the California Offset Project, which was submitted on May 3, 2000) required by Paragraph 91 of the Consent Decree.

The projects are as follows:

1. Heavy-Duty Truck SCR Demonstration and In-Use Testing
2. Heavy-Duty Diesel Truck Aftertreatment Retrofit Project
3. Ultra-Low In-Cylinder Emissions Engine

Mack Trucks, Inc. is exercising Confidential Business Information only with regard to the three attachments contained in the Ultra-Low In-Cylinder Emissions Engine write-up, which are clearly marked CONFIDENTIAL BUSINESS INFORMATION.

To the best of my knowledge, after thorough investigation, I certify that the information contained in or accompanying this submission is true, accurate, and complete. I am aware that there are significant penalties for knowingly submitting false information, including the possibility of fines and imprisonment for knowing violations.

Glenn O. Shetter

Glenn O. Shetter
On Behalf of Mack Trucks, Inc.

Enclosures:

Scope of Work for a Heavy-Duty Diesel Truck Selective Catalytic Reduction (SCR) Demonstration and In-Use Testing Project along the I95 Highway Corridor

Submitted to the U.S. Environmental Protection Agency (EPA) by

Mack Trucks, Inc.
and
Northeast States for Coordinated Air Use Management (NESCAUM)
May 23, 2000

ABSTRACT

This is a scope of work for a joint project to equip 10 highway heavy-duty vehicles with selective catalytic reduction ("SCR") in the Northeast states as part of Mack Trucks' "Company Proposed" projects to reduce oxides of nitrogen (NOx) emissions from heavy-duty engines. In the demonstration, all trucks will be tested for NOx, particulate (PM), hydrocarbon (HC), and carbon monoxide (CO) air pollutant emissions under in-use conditions to quantify the emissions benefits/affects from this control strategy. In addition to criteria pollutant testing, one or more trucks will be tested for nitrous oxide (N_2O) and ammonia (NH_3) emissions in a laboratory.

PARTICIPANTS

Suggested Partners: Mack Trucks, Siemens-Westinghouse Power Corporation, Donaldson Company, NGK-Locke, other equipment suppliers, truck fleet operators, the Northeast States for Coordinated Air Use Management (NESCAUM) and NESCAUM member state agencies, urea and urea infrastructure suppliers.

Benefit of NESCAUM / State Involvement: NESCAUM has represented the pollution control programs in the eight northeast states for over 30 years. In the areas of air pollution control, diesel technology, pilot study design and emissions testing and assessment, we offer the combined expertise of our in house staff and the technical staff of the northeast states. This technical, regulatory and institutional expertise offered by NESCAUM will serve the project in numerous ways. First, NESCAUM is the only organization outside of California with actual experience conducting heavy duty vehicle retrofit projects. We are presently conducting active projects at three sites and will bring real world problem solving to this collaboration. Moreover, NESCAUM has been a national leader in the development of emissions reduction credit programs and measurement protocols. Second, NESCAUM has maintained a highly energetic Heavy Duty Engine State Working Group over the past three years. Active state involvement in this project will add credibility, substantial logistical support and increased visibility if desired. Third, NESCAUM's reputation within government, industry, and the environmental community for integrity and technical accuracy will provide added credibility to the project goals and results. Last, NESCAUM has substantial experience managing logistically complex, multiparty projects and documenting these efforts through technically detailed yet accessible reports. Having strong existing relationships with many of the proposed partners listed above, we feel well suited to provide similar organizational support for this effort.

BACKGROUND

Studies have shown that equipping heavy-duty engines with selective catalytic reduction (SCR) can achieve significant reductions in heavy-duty engine NOx emissions. While SCR retrofit of stationary external combustion engines to reduce NOx emissions is widespread, the installation of SCR in mobile sources is relatively new. Recently, several pilot studies conducted by Siemens Westinghouse Corporation and other companies have shown significant NOx emissions reductions in heavy-duty trucks and diesel generators through the use of SCR.[1] An SCR evaluation program for highway heavy-duty trucks in the Northeast is needed to assess the emissions reductions that can be achieved with this technology and to explore urea infrastructure development issues.

PROJECT GOALS

The goals of this project are to:

1. Reduce NOx emissions from in-use heavy-duty diesel engines in northeast urban, ozone non-attainment areas;
2. Assess the effectiveness of the SCR control technology in reducing NOx under both steady state and transient conditions;
3. Quantify the emissions reductions achieved from the SCR program;
4. Demonstrate prototype emissions measuring devices that gather continuous data on NOx emissions;
5. Assess the effectiveness of the system to control secondary emissions such as N_2O and NH_3 to minimal levels;
6. Develop an understanding of the practical considerations involved in installing SCR technology and a urea infrastructure for in-use highway diesel engines which operate in vocational, over the road or long haul applications.

EMISSION REDUCTIONS

The project will provide real and quantifiable NOx emissions reductions in the Northeast. In these states ozone pollution consistently exceeds federal health standards.[2] Project participants will aim to reduce NOx to 1.5 g/bhp-hr (about a 70 percent reduction) in the

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[1] Mueller, Raimund; Roemich, Herbert; Joisten, Michael "SINOx SCR Systems - An Experience Report on Reducing Emissions of Criteria Pollutants of Stationary and Mobile Sources" ICAC Forum '98 Cutting NOx Emissions.

[2] NESCAUM "Heavy-Duty Engine Emissions in the Northeast," 1997.

study vehicles through the use of urea SCR. Achieving a 70 percent reduction in long haul heavy-duty diesel engines could lower NOx emissions by as much as three quarters of a ton per year, per vehicle.[3] Over the 3 years of the project, this would equal 22.5 tons of NOx. If the SCR systems remain on the ten trucks after the completion of the demonstration program, this total would increase.

LOCATION OF ENVIRONMENTAL BENEFIT

Project participants will select long haul trucks that travel along the I95 corridor. In choosing the I95 corridor as a focus of the study area, the project aims to reduce NOx along one of the major highway corridors in the region, where the impact from long haul heavy-duty diesel NOx emissions is great. Mack and NESCAUM will work to find a fleet or several fleets that travel from New Jersey to Massachusetts (or further north if possible) along I95. Thus, the NOx reductions that result from the project are anticipated to occur in New Jersey, New York, Connecticut, Massachusetts, and Rhode Island.

In developing operational data and a final estimate of the cost per ton of NOx reduced from the use of SCR in heavy-duty highway engines, the project will assist in determining the viability of expanded use of SCR technology in the heavy-duty truck sector.

NEW TECHNOLOGY DEMONSTRATIONS

The project will demonstrate the use of SCR technology in heavy-duty highway diesel trucks. Over the past year Mack Trucks has worked with Siemens Westinghouse Power Corporation to engineer an SCR system for E-TECH 350 hp class VIII engine. This project will provide in-use demonstration and assessment of this engine model with a urea SCR system and will be one of the first demonstrations of SCR in mobile sources in this region.

In addition to demonstrating a new application of SCR technology, project participants will utilize a prototype emissions monitoring device to test NOx emissions under various driving conditions both before and after the SCR catalyst. The device gathers continuous baseline and post-catalyst NOx emissions data which can be stored using a laptop computer. This equipment could be used to monitor the effectiveness of the SCR equipment over a period of several hou:s. The effectiveness of the device will be determined through conventional emissions testing methods.

Another new technology that may be used as part of this project is one which detects the presence of urea. The purpose of using this device is to address concerns that operators may fill up their urea tanks with water in order to avoid any inconvenience associated with re-filling the on-board urea tanks with urea. Project participants will assess whether the device can effectively determine that the urea tanks are filled with urea.

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[3] Assumes a 350 hp engine operating 2,000 hours a year, at 6 g/bhp-hr NOx, with a load factor of .22.

Last, Mack Truck engineers may program electronic controls to give truck operators an incentive to refill the urea tank. The purpose of these controls is to develop experience with a quality assurance system for the urea SCR system. Regulators have expressed legitimate concerns that while the urea SCR system may reduce NOx emissions very effectively, if operators do not refill the urea tanks as required, no reductions will be realized. If the urea tank runs dry or is filled with a liquid other than urea, a warning light will illuminate and engine performance will be limited until the problem is corrected.

PROJECT APPROACH/SCOPE OF WORK

The project will take place in eight phases:

1) Develop detailed project plan and goals clarification;
2) Conduct survey of highway heavy-duty fleets and procurement of trucks for participation in the project;
3) Develop SCR system and monitoring method for truck NOx emissions and urea consumption;
4) Install the SCR equipment and urea infrastructure;
5) Conduct emissions testing to determine reduction of pollutants from the installation of the SCR systems;
6) Conduct emissions testing to prove out NOx monitoring system;
7) Develop quantification methods
8) Document results.

1. Development of A Detailed Project Plan and Program Implementation

Upon determination of available project funding and in-kind assistance, project participants will meet to finalize project plan and timelines. It is anticipated that a meeting will take place in August to finalize the project timeline, workplan, report preparation strategy, and other elements key to the successful completion of the demonstration. In addition, project workgroups or teams may be formed around substantive issues and/or site locations. For example, an emission testing workgroup will be established to develop a testing protocol. We propose to balance the convenience of concentrating technology in a few locations with the benefit of involving more states and communities in the effort.

Throughout the project, Mack, Volvo, and NESCAUM will coordinate elements of the project such as emissions testing and urea infrastructure development. Volvo will participate in project meetings, such as the proposed August meeting. In addition, Volvo will participate in conference calls so that information on technical and implementation issues can be shared.

2. *Fleet Survey*

Development of an Inventory and Route Information for Truck Fleets

During this phase of the project, fleets will be surveyed by project participants to determine the appropriate vehicles to equip with SCR systems. An objective of the project is to equip new engines such as the Mack E-TECH engines with SCR and thus locating fleets with trucks on order from Mack will be important. For new truck SCR use, Mack Trucks will determine which fleets in the region are ordering new class eight trucks. Once this has been done, information on mileage driven annually, routes, and fueling practices will be gathered from potential fleets. When candidate fleets are selected, project participants will discuss the program with the fleet operators.

In addition to locating new vehicles on order for SCR retrofit, project participants will develop a survey of state fleet vehicles, U.S. Postal Service vehicles, and other fleet vehicles for possible inclusion in the project.

Example of Possible Fleet Vehicles to be Equipped with SCR:

The following provides information on the type of fleet the project participants will work to include in this SCR program. Class eight trucks are desirable because these trucks travel long distances under conditions that are relatively steady state. Since the trucks travel long distances, mass NOx emissions during the trips are high. Important in selection of a fleet for inclusion in this project is a previous working relationship between the fleet and state regulators and Mack Trucks. Potential highway fleets to be included in the project are listed below:

APA Transportation, based in NJ (near NYC)
Air Products, based in Trexlertown, PA
Lily Transportation, based in Needham, MA
Matlack, based in Swedesboro, NJ
New Penn, based in Lebanon, PA
Pitt Ohio, based in Pittsburgh, PA
Ryder, throughout the Northeast
UPS, throughout the Northeast

All of these companies operate Class 8 trucks. Some of these fleet vehicles are manufactured by Mack Trucks. All of these fleets will be considered for inclusion in the SCR demonstration program.

During the vehicle procurement phase of the project, fleets will be assessed for eligibility.

3. SCR Fabrication and Infrastructure Planning

During this phase of the project, the urea injection system and catalyst, tampering resistant strategy, and installation will be completed on ten vehicles. The retrofit of the vehicles will be based upon work that Mack Trucks has done over the past year on the E-TECH engine. The SCR equipment manufacturer will fabricate the SCR catalysts and injection system. The project is geared toward new vehicles. The exact types of vehicles to be used will be determined at the start of the project.

Also during this time, fabrication and installation of the urea infrastructure will be completed in coordination with the truck fleet and the urea infrastructure supplier. Urea tanks will be installed either on site, at garages, or at truck stops along a predictable travel route for the fleet vehicles. Urea tanks will need to be installed at urea filling stations (truck terminals or truck stops). These tanks should hold approximately 500 gallons of urea. Urea tanks will also be installed on each of the trucks participating in the demonstration. These tanks will hold approximately 15 gallons of urea.

There are two possible approaches to developing the urea infrastructure for this project. In one scenario, urea tanks and infrastructure would be installed at fleet terminals or fleet garages. In this case, trucks that travel along I95 between Boston and Newark, for example, would be good candidates. These trucks are able to make their trips on one tank of diesel and since urea containers on the trucks need to be refilled every time the diesel tank is filled up, refueling of both fluids could occur at the terminals. Urea infrastructure (tanks, dispensers, meters, and other necessary equipment) could be installed at the truck terminals on both ends of the trip.

Another approach would be to choose a fleet that travels all the way from New Jersey to Maine. In this case, urea infrastructure would need to be installed both at the fleet terminals or garages and along I95 so that truck operators could replenish the urea for the SCR system. In this case, project participants will work with Travel Ports of America, Truck Stop Association of America, and other truck stop operators in the region to identify and establish appropriate urea infrastructure locations.

The approach will be chosen in coordination with truck fleet managers/owners that are participating in the project. In selecting participating vehicles, a preference will be given to those truck fleets that are willing to re-fill their on-board urea tanks along the I95 corridor.

4. Installation of SCR Devices

Once Siemens has manufactured the SCR systems, Mack will install the devices on the ten vehicles at Mack facilities. This will involve engineering and design to adapt the SCR system to the selected engine/truck models. Space constraints will require design changes to fit the urea tanks and SCR catalyst on the truck. Installation documentation will be developed as well as engineering documentation for adaptation of the SCR system for the specific engine model.

5. *Emissions Testing*

Detailed emissions measurements and engine use profiles will be conducted for all vehicles. Possibilities for emissions testing include laboratory facilities at West Virginia University, Environment Canada, and other testing labs, in-use testing using EPA's on highway emissions trailer or the Real Time On Board Vehicle Emissions Recorder (ROVER), West Virginia's chassis dynamometer, Environment Canada's mobile sampling system. Some combination of the above will be necessary in order to sample criteria pollutants, N_2O, and NH_3. Technical aspects of the testing program are:

- Development of in-use testing protocol. The protocol will establish and describe how testing will occur in the laboratory and under in-use conditions and how the on-board NOx emissions monitors will operate. The protocol will describe how testing for PM, HC, CO, N_2O and NH_3 will occur.
- Criteria Pollutant Testing: Project participants will consider using bag samples and chemiluminescent detectors for NOx, non-dispersive infrared detectors for CO, flame ionizer detectors for HC. Alternatively, continuous NOx, CO, and HC samples could be collected using NDIR technology (such as with the ROVER). Electrochemical emissions testing equipment may also be considered. For PM testing mass filtration and dilution will need to be conducted.
- Secondary Pollutant Testing: A method for gathering NH_3 and N_2O will be developed. This testing may need to occur in a testing facility. A potential method for measurement is Fourier Transform Infrared technique. This has been used successfully in the past.
- Sampling method: A sampling system which draws exhaust from both upstream and downstream of the catalyst would be optimal for simultaneous baseline (engine out) and post-catalyst emissions. However, a testing program can be designed to measure before and after the installation of the control equipment if necessary.
- Engine Use Profiles Development: data on engine rpm, exhaust temperature, and throttle position will be collected by accessing the ECM monitor if possible. Other methods for gathering this information are available if accessing the ECM cannot be done.

A possible testing method is described in this section. This method may change as project proponents refine this proposal. Project proponents propose to monitor the SCR system and the emissions sensing device in four "rounds" of emissions testing. The four components are described below:

a) Initial emissions testing at the time of SCR system installation:

All ten vehicles will be tested for the following pollutants over the road: NOx, CO, and HC using a mobile unit such as the EPA ROVER or Environment Canada's mobile testing system. Measurements will be taken both upstream and downstream of the SCR system and will yield continuous readings for NOx, CO, HC in grams per mile, and possibly grams per brakehorsepower hour (if the engine ECM can be accessed for torque data). While the testing cycle will not be consistent from vehicle to vehicle, real world emissions data will be gathered and the design of the system will allow for an accurate assessment of baseline and after catalyst emissions.

In addition, during this over-the-road testing the trucks will be equipped with a prototype emissions monitoring device. The device will monitor NOx emissions continuously both upstream and downstream of the catalyst. During in-use testing, baseline and after catalyst data will be gathered. After testing the readings from the mobile testing unit and the prototype monitoring device will be compared.

Three of the vehicles will be sent to an emissions testing laboratory (example laboratories are West Virginia University and Environment Canada). The vehicles will be tested on an accepted chassis dynamometer cycle that is representative of in-use conditions. Sampling for NOx, HC, CO, PM will be done using laboratory grade equipment. An example of laboratory grade equipment is a Horiba chemiluminescent detector for NOx. During this testing, baseline emissions will be determined and the prototype emissions detector will be tested for accuracy. Emissions samples will be taken upstream and downstream of the prototype emissions detector in order to assess the accuracy of the prototype sensor.

b) Emissions testing six months, twelve months, and two years after installation

During this phase of emissions testing, the three trucks that originally were tested on an engine dynamometer will be sent back to the emissions testing laboratory. Before they are sent back, the emissions testing contractor will gather data during in-use driving. Data will include: exhaust temperature, rpm, torque (if possible). From these data, an in-use driving cycle will be developed for replication in the emissions testing laboratory. The chassis dynamometer will be programmed to run this in-use cycle. The three vehicles will be tested in the laboratory on both the in-use cycle and on the established cycle (such as the West Virginia cycle) that they were tested on in the phase I of emissions testing.

Also during this phase, the other seven trucks will be re-tested under normal driving conditions with the mobile testing unit. The testing will both establish baseline and post baseline emissions six months after the SCR installation. Baseline data will provide information on engine emissions "drift." As in Phase I of testing, emissions data will be gathered upstream and downstream of the SCR system, simultaneously if this is possible. Alternatively, project participants will measure load from the engine electronic control module or conduct emissions tests over the same test track.

c. Emissions Testing to Prove Out NOx Sensor

An important component of the emissions testing program will be an assessment of the continuous NOx monitors. The purpose of this aspect of the emissions testing will be to ensure that changes in NOx emissions detected by the system are accurate. Since the emissions credit protocol will rely on the results of the continuous NOx measurements, establishing the accuracy of the measurements under a variety of ambient and engine conditions, and over time will be critical. Testing methods will include those described above.

d. Emissions Testing Costs

It is important to note that project participants will not exceed the allotted budget for emissions testing. Project participants have outlined various options for conducting emission testing. The proposed plan is ambitious and may need to be scaled back to some degree and thus some of the testing components may be omitted from the project if they prove too costly. Since the primary goal of the project is to achieve NOx emission reductions, testing costs will be kept within budget so as not to reduce the number of trucks that are equipped with SCR devices.

6. Develop Quantification Methods

In addition to the emissions data collected during in-use testing, monitoring of daily fill up records for fuel and urea consumption as well as urea purchase records will be examined by the project participants. While this method is not sufficient to ensure that the urea SCR system is being used properly, the records will give an indication of whether or not enough urea has been purchased to support the system during the project.

To facilitate the measurement of total NOx reduction benefits and the creation of Emission Reduction Credits (ERC's) it is necessary to develop robust credit creation protocols. NESCAUM has led several multi-stakeholder efforts to develop credit quantification guidelines and protocols. Over the last year NESCAUM has worked with member states and the U.S. EPA to develop a method to quantify and calculate SIP credits from the retrofit of diesel engines (both highway and nonroad) with emission control devices. This work will provide a model for our efforts to quantify the credits associated with the retrofit of highway heavy-duty vehicles with SCR.

7. Documentation of Results / Final Report

Both the research and policy communities should benefit from the knowledge generated through this project. Protocols must be developed at the outset to ensure data consistency. Throughout the course of the initiative, project participants should seek to document both unexpected challenges and pleasant surprises. Data should be collected, quality assured and analyzed at appropriate intervals. Project participants may choose to publish results in peer reviewed literature either collectively or independently. NESCAUM is prepared to coordinate and/or draft a final report documenting the emissions reductions, performance of the SCR systems on truck engines and assessment of the feasibility of commercial scale application. All project documentation will be reviewed by project participants and will recognize the existence of confidential business information where appropriate.

IN-KIND CONTRIBUTION

In-kind contributions to this project will be in the form of state staff time, potential siting of urea tanks on state property, and/or use of state fleet vehicles, permitting work, technical assistance, possible development of an over the road testing unit and operation of the unit, and/or the dedication of two full time equivalents to training, use, and maintenance of an EPA provided over the road testing device. In addition, some states through participation in the Clean Fuel Fleets program have developed working relationships with fleet operators in their states. State staff can be counted on to facilitate project implementation through these existing relationships. In order to test for ammonia and nitrous oxides, an emissions testing contractor will be hired. In-kind contributions from the emissions testing contractor will be required for participation in the project. The total in-kind contribution will be equivalent to several hundred thousand dollars.

ELEMENTS TO BE RESOLVED

Technical work:

Mack and Siemens have equipped one truck with an SCR system to date. For this truck, engine mapping, bracket fabrication, placement of the SCR system on the truck, and preliminary emissions testing have been completed. This initial experience will help to speed the development and installation of the SCR systems onto the ten trucks planned for this project. Technical work yet to be completed includes mapping of selected engine models and work to determine placement of the SCR system on trucks currently in production. Development of an emissions testing protocol is also needed.

Fleet Selection:

Potential fleets for inclusion in the project have been identified. Work to be completed in order to select trucks for the project includes: contacting companies to assess interest in participating in the project; and collecting information on trucks, routes, fueling arrangements, and other important elements.

Urea Infrastructure

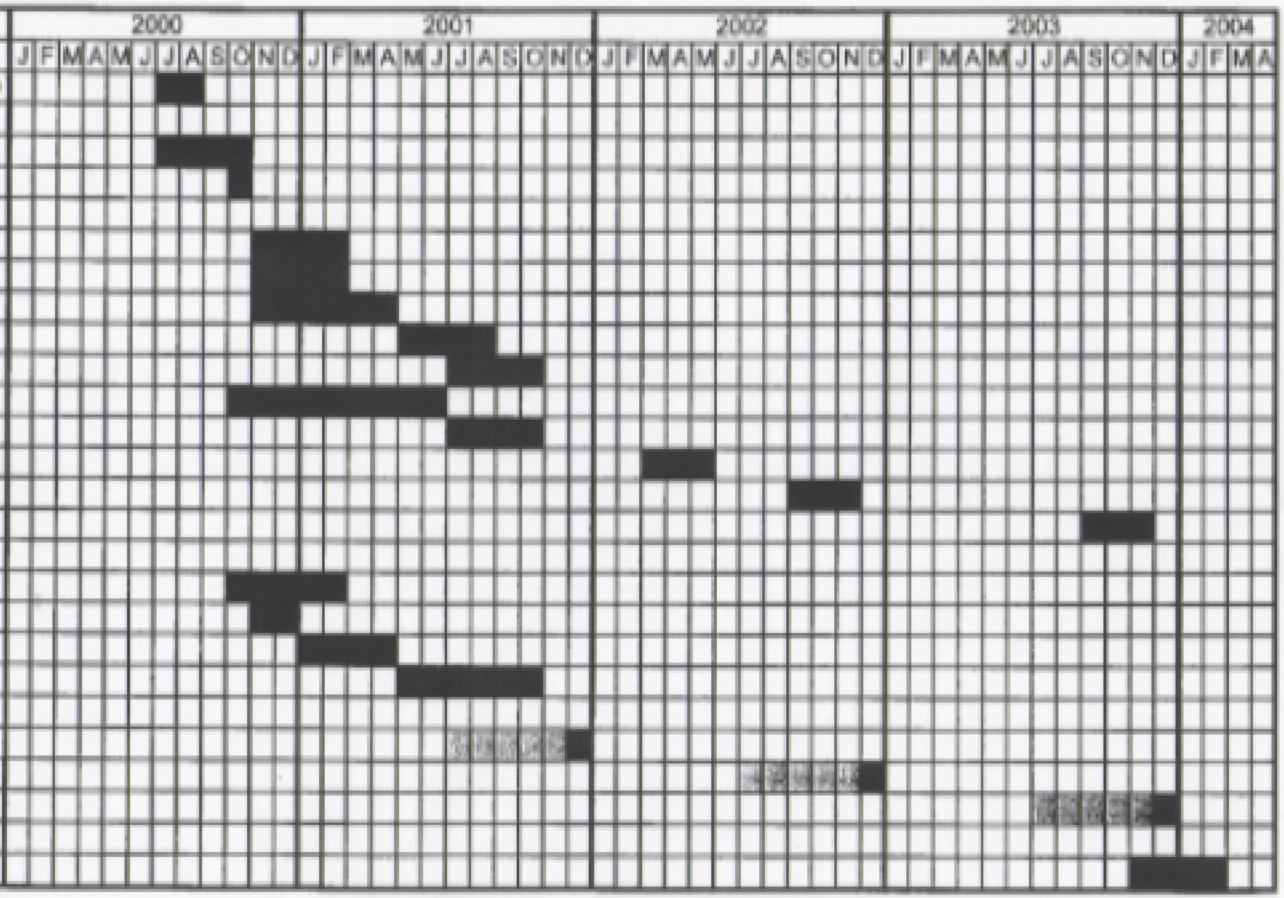
Initial contacts to urea suppliers and to urea infrastructure suppliers have been made. Work to be completed in order to supply urea to the trucks in the demonstration includes determining: if the urea will be re-fueled at truck terminals or along the I95 corridor;

which supplier will provide urea; what kind of tanks will be needed; and what the permitting issues are associated with urea tank placement.

In short, significant work has been done in planning for the project, but important elements are not yet finalized which will be key to successful implementation. These elements will be finalized soon after the project initiation date.

PROJECT SCHEDULE - SCR AFTERTREATMENT

task	start	end
project planning	Jul-00	Aug-00
truck and engine selection		
survey of fleet	Jul-00	Oct-00
final selection	Oct-00	Oct-00
truck, engine, and SCR preparation		
engine application testing	Nov-00	Feb-01
vehicle engineering	Nov-00	Feb-01
component fabrication	Nov-00	Apr-01
SCR installation	May-01	Aug-01
truck delivery	Jul-01	Oct-01
emissions testing planning	Oct-00	Jun-01
initial test	Jul-01	Oct-01
2nd test - 6 months	Mar-02	May-02
3rd test - 12 months	Sep-02	Nov-02
4th test - 24 months	Sep-03	Nov-03
urea filling stations		
site selection	Oct-00	Feb-01
equipment selection	Nov-00	Dec-00
pump station fabrication	Jan-01	Apr-01
installation	May-01	Oct-01
reports		
report 1 (prepare and deliver)	Jul-01	Dec-01
report 2 (prepare and deliver)	Jul-02	Dec-02
final report (prepare and deliver)	Jul-03	Dec-03
post-test		
certify or remove SCR	Nov-03	Feb-04



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Scope of Work for a Heavy-Duty Diesel Truck
Aftertreatment Retrofit Project

Submitted to the U.S. Environmental Protection Agency (EPA)
by

Mack Trucks, Inc.
and
Northeast States for Coordinated Air Use Management (NESCAUM)
May 23, 2000

ABSTRACT

This is a scope of work for a joint project to retrofit 185 heavy-duty vehicles with diesel oxidation catalysts (DOC) or diesel particulate filters (DPFs) in the Northeast states as part of Mack Trucks' "Company Proposed" projects to reduce PM, HC, and CO emissions from heavy-duty engines. This project will include 150 trucks with diesel oxidation catalysts (DOC), 30 trucks with diesel particulate filters (DPF), and 5 trucks with a combination of DPF and selective catalytic reduction (SCR). These last 5 trucks are also involved in the "SCR Demonstration and In-Use Testing Project" and are included here to investigate the interactions between these technologies. After one and two years in operation, several DOCs and DPFs will be removed and evaluated in an emissions testing cell. Exhaust backpressure will be monitored on several trucks as an indicator of aftertreatment plugging and/or failure. If successful during the two-year tracking period, these units will remain in service after conclusion of the project.

PARTICIPANTS

Suggested Partners: Mack Trucks, Engelhard Corporation, Donaldson Company, truck fleet operators, the Northeast States for Coordinated Air Use Management (NESCAUM) and NESCAUM member state agencies.

Benefit of NESCAUM / State Involvement: NESCAUM has represented the pollution control programs in the eight northeast states for over 30 years. In the areas of air pollution control, diesel technology, pilot study design and emissions testing and assessment, we offer the combined expertise of our in house staff and the technical staff of the northeast states. This technical, regulatory and institutional expertise offered by NESCAUM will serve the project in numerous ways. First, NESCAUM is the only organization outside of California with actual experience conducting heavy duty vehicle retrofit projects. We are presently conducting active projects at three sites and will bring real world problem solving to this collaboration. Moreover, NESCAUM has been a national leader in the development of emissions reduction credit programs and measurement protocols. Second, NESCAUM has maintained a highly energetic Heavy Duty Engine State Working Group over the past three years. Active state involvement in this project will add credibility, substantial logistical support and increased visibility if desired. Third, NESCAUM's reputation within government, industry, and the environmental community for integrity and technical accuracy will provide added credibility to the project goals and results. Last, NESCAUM has substantial experience managing logistically complex, multiparty projects and documenting these efforts through technically detailed yet accessible reports. Having strong existing relationships with many of the proposed partners listed above, we feel well suited to provide similar organizational support for this effort.

BACKGROUND

Studies have shown that equipping or retrofitting heavy-duty engines with DOCs and DPFs have resulted in PM reductions of approximately 20% for DOCs and approximately 90% for DPFs.[1] DOCs and DPFs are also capable of reducing HC by 80% or more. While over 1 million DOCs have been installed on diesel trucks as original equipment by manufacturers to comply with the 1994 PM standard, retrofitting outside of the Urban Bus Program has until recently been rare. The Urban Bus Program was established in 1993 and requires transit bus operators located in consolidated metropolitan districts with populations of 750,000 or greater to retrofit urban buses. Although PM reduction is the primary focus of this project, HC reduction is also of significant value. No NOx reduction benefit is expected from DOCs and DPFs.

DPFs have been used in the mining and the materials handling sectors for years to reduce worker exposure to particulate emissions. Efforts in the Northeast and elsewhere to retrofit nonroad equipment and urban buses with filters have yielded promising results. Recent work by New York State to retrofit urban buses with continuously regenerating particulate filters along with very low sulfur fuel use has yielded excellent results. Even with these successful demonstrations, considerable work needs to be done with filters before they can be used on a widespread basis. Filters require relatively high exhaust temperatures for consistent regeneration and this can pose a challenge given the widely varying duty cycles of heavy-duty trucks. For example, long idle periods and light-load operation present a situation where the DPF collects PM but cannot regenerate. Although DPFs offer high potential PM reduction, the risks of plugging and/or failure indicate that caution must be taken to understand these issues prior to widespread implementation. Thus, the number of DPFs involved in this project has been limited to 35.

Developing an understanding of the interaction between DPF and SCR is a secondary goal of this project. In order to meet future emissions standards, it is likely that both PM and NOx aftertreatment with high reduction efficiencies will be required. Both DPF and SCR technologies rely on exhaust heat to promote chemical reactions which reduce emissions. Stacking technologies in series may have negative impacts relating to catalyst heat-up times, emissions reduction efficiency, exhaust backpressure, and regeneration (DPF only). Understanding these interactions and optimizing the combination of

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[1] Ainslie, Rideout, Cooper, McKinnon "The Impact of Retrofit of Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment" SAE March, 1999 and other SAE papers

technologies will be important to meeting future emissions standards such as those proposed for 2007 model year engines.

The Mack program to retrofit diesel trucks with filters and oxidation catalysts and to conduct durability emissions testing on highway heavy-duty trucks in the Northeast will build on considerable state efforts to retrofit in use vehicles and to achieve emission reductions from existing diesels and will augment efforts to implement widespread retrofit programs.

PROJECT GOALS

The major project goal is to:

1. Install aftertreatment on the largest possible number of vehicles through retrofit of existing and new trucks to provide a significant reduction in PM emissions in the near-term.

Minor project goals are to :

2. Assess the effectiveness of DOCs and DPFs in reducing emissions during steady state and transient cell tests;
3. Develop an understanding of interactions when combining DPF and SCR technologies in series;
4. Assess DOCs and DPFs over the course of field-test operation in terms of emissions reduction.

EMISSION REDUCTIONS

Project participants will aim to reduce PM by 20 percent or more through the use of DOCs. The 150 trucks with DOCs will reduce PM by a total of 1,020 lb/yr. This percentage reduction equates to 6.8 lb/yr per truck.[2]. This assumes that post-1994 vehicles will be retrofitted. Greater PM mass reduction may be achieved by retrofitting pre-1994 trucks at PM levels of 0.25 g/bhp-hr. Project participants will aim to include both 1994 and pre-1994 engines in the retrofit program. Fleet vehicles such as those owned by states will likely include both pre and post 1994 vehicles. There is a greater risk of catalyst plugging and/or failure at higher engine-out PM levels. Further discussions with the aftertreatment supplier are required to assess this risk. Availability of trucks, mileage accumulated per year, and customer risk must be considered in the decision as to which model year trucks to retrofit.

Participants will aim to achieve a 90 percent reduction in heavy-duty engines through the use of PM filters. This reduction equates to 30.5 lb/yr PM reduction per truck or 1,068 lb/yr for the 35 trucks. If the filters remain on the 35 trucks after the completion of the

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[2] assumes 350 bhp engine, 0.22 load factor, 2000 hr/yr utilization, and 0.10 g/bhp-hr base PM level for engines with 1994 and after certification

demonstration program, this total would increase. In addition, HC and CO pollution will be reduced at least 50 percent.

The sum of all trucks involved will result in a PM mass reduction of 2,088 lb/yr or approximately 1 ton/yr assuming all post-1994 trucks are retrofitted.

LOCATION OF ENVIRONMENTAL BENEFIT

Project participants will include both long haul and vocational trucks for this demonstration. Trucks will be included that travel up and down the I95 corridor and trucks that operate in congested urban areas such as New York City. In choosing long haul trucks that travel the I95 corridor as one focus of the study area, the project aims to reduce PM, HC, and CO along one of the major highway corridors in the region, where the impact from long haul heavy-duty diesel emissions is great. In choosing trucks that operate in congested urban areas, project participants will aim to reduce PM, HC, and CO pollution in areas that are especially burdened by air pollution and to address environmental justice issues. For example, some of Mack Trucks' largest customers are waste hauling companies. Participants will take advantage of the need to reduce pollution in urban areas and the availability of Mack Trucks in these areas.

In the project, a preference will be given to retrofitting trucks that operate locally. This is the case for three reasons: first, local trucks typically operate in a stop and go manner which increases particulate emissions; second, environmental justice reasons; and third, retrofitting trucks that operate locally will allow project participants to retrofit state fleet vehicles and to reduce pollution in states which will not benefit from the SCR project, such as some of the more northern states.

PROJECT APPROACH/SCOPE OF WORK

The project will take place in six phases:

1) Develop detailed project plan and goals clarification;
2) Conduct survey of heavy-duty fleets and procurement of trucks for participation in the project;
3) Hardware design and fabrication.
4) Install the DPFs and DOCs on the 185 trucks;
5) Conduct durability emissions testing to determine durability of DOCs and DPFs;
6) Document results.

1. Detailed Project Plan

Upon determination of available project funding and in-kind assistance, project participants will meet to finalize the project plan and timeline. It is anticipated that a meeting will take place in August to finalize the project timeline, workplan, report preparation strategy, and other elements key to the successful completion of the demonstration. In addition, project workgroups or teams may be formed around substantive issues and/or site locations. We propose to balance the convenience of concentrating technology in a few locations with the benefit of involving more states and communities in the effort.

2. *Fleet Survey*

Development of an Inventory and Route Information for Truck Fleets

During this phase of the project, fleets will be surveyed by project participants to determine the appropriate vehicles to equip with DOCs and DPFs. An objective of the project is to retrofit both long haul and city trucks such as refuse haulers with emission control devices. Information on mileage driven annually, routes, exhaust temperatures, and configuration of exhaust systems will be gathered from potential fleets. When candidate fleets are selected, project participants will discuss the program with the fleet operators. Some fleet operators in the Northeast have already expressed enthusiasm for participating in the project. New York City Sanitation is one such fleet.

Example of Possible Fleet Vehicles to be Equipped with DOCs and DPFs:

The following provides information on the type of fleet the project participants will work to include in this retrofit program.

Waste Haulers and Local Fleets:

- BFI
- Casella Waste
- Maine Department of Transportation
- New York Sanitation
- Republic Industries
- Superior Services
- Waste Management

Long Haul Fleets:

- APA Transportation
- Air Products
- Lily Transportation
- Matlack
- New Penn
- Pitt Ohio
- Ryder
- UPS

All of these companies operate Class 8 trucks. Some of these fleet vehicles are manufactured by Mack trucks. All of these fleets will be considered for inclusion in the aftertreatment retrofit project. During the vehicle procurement phase of the project, fleets will be assessed for eligibility.

3. *Hardware Design and Fabrication*

Hardware design and fabrication for DOCs and DPFs will include engineering the control technology into the truck exhaust system. Specifically, aftertreatment packaging, mounting brackets, and exhaust pipes must be designed and fabricated. Where possible, mufflers with integral aftertreatment will be designed and installed similar to the original muffler. Project participants may limit the number of truck models in order to minimize the mounting arrangements required and to maximize the number of exhaust control units installed. During this phase of the project, the truck manufacturer, aftertreatment supplier, and exhaust system supplier will work closely to develop and fabricate components suitable for retrofitting. Components required to monitor exhaust backpressure will also be designed and fabricated.

4. *Truck Installation*

This project will include retrofits of existing and new trucks with emission control devices and thus truck installations will vary accordingly. Retrofits of existing trucks may be done on-site or at a local Mack dealership. New trucks will be built at Mack vehicle assembly plants using standard exhaust systems. Upon completion, new trucks will be delivered to a Mack Modification Center where the exhaust systems will be altered to include aftertreatment. Exhaust backpressure monitoring equipment will be mounted on some trucks. In five cases, trucks will be equipped with both SCR systems and DPFs. In these cases, the DPF will be installed after one year of SCR operation alone in order to baseline the SCR system and determine impact of DPF.

5. *Emissions Testing*

Emissions measurements of a sample of DOCs and DPFs will be taken in the laboratory after the units have been installed for several thousand hours. The emissions testing program will be geared toward durability testing of the units. Some initial testing will be conducted for new vehicle installation at the Mack facility. For durability testing, the DOCs and the DPFs will be removed from the vehicles and sent to an emissions testing laboratory. There the units will be evaluated in engine emissions test cells. The units will be tested for all criteria pollutants to ensure that they have continued to reduce pollution even after several thousand hours in use. NESCAUM has conducted durability testing of several units in this way and found this method to be very cost effective. Other methods will also be considered. Southwest Research Institute, West Virginia University, Environment Canada, and others are potential testing laboratories. In addition, exhaust backpressure will be recorded daily for some test vehicles. Changes in this measurement may indicate aftertreatment plugging and/or failure.

6. *Documentation of Results / Final Report*

Both the research and policy communities should benefit from the knowledge generated through this project. Protocols must be developed at the outset to ensure data consistency. Data should be collected, quality assured and analyzed at appropriate intervals. Project participants may choose to publish results in peer reviewed literature either collectively or independently. NESCAUM is prepared to coordinate and/or draft a final report documenting the emissions reductions, performance of the DOC and DPF systems on truck engines and assessment of the feasibility of commercial scale application for DPFs. All project documentation will be reviewed by project participants and will recognize the existence of confidential business information where appropriate. NESCAUM will collect information and assemble reports including project status, conclusions, and recommendations. Reports will be issued after completion of installations, after one year of operation, and after two years of operation to project participants and the EPA.

In-Kind Contribution

In-kind contributions to this project will be in the form of state staff time, use of state fleet vehicles for retrofitting, and technical assistance. In addition, some states through participation in the Clean Fuel Fleets program have developed working relationships with fleet operators in their states. State staff can be counted on to facilitate project implementation through these existing relationships.

ELEMENTS TO BE RESOLVED

A draft workplan for this project has been developed and technical work has been done which will form the foundation of this DOC and DPF emission reduction project. The technical work that has been done to date will allow for successful installation of control devices on the 185 trucks. The planning work that has and is being done at this time will enable project participants to identify appropriate fleet vehicles for inclusion in the project. In other areas such as emissions testing, preliminary plans have been established. Elements to be resolved and that are key to the successful completion of this project include 1) finalizing plans for emissions testing; 2) identifying fleets that will participate in the project; and 3) identifying contractors to supply emission control devices.

In short, significant work has been done in planning for the project, but important elements are not yet finalized which will be key to successful implementation. These elements will be finalized soon after the project initiation date.

PROJECT BUDGET - PARTICULATE AFTERTREATMENT

truck manufacturer		
truck engineering		
exhaust bracket fabrication		
backpressure instrumentation		
truck installations		
durabiility verification		
engineering support during field-test	$	364,000
engine testing		
initial application testing		
emissions test 1 (parts removed for cell test)		
emissions test 2 (parts removed for cell test)	$	200,000
truck fleet		
maintenance, service, and recordkeeping		
compensation for truck downtime	$	90,000
diesel aftertreatment supplier		
diesel oxidation catalysts		
diesel particulate filters		
DOC and DPF analysis		
engineering support during field-test	$	385,000
exhaust system supplier		
canning of DOC/muffler assemblies		
canning of DPF/muffler assemblies		
engineering support during field-test	$	121,000
NESCAUM and member states		
project planning		
project coordination		
report writing	$	150,000
project total	$	1,310,000

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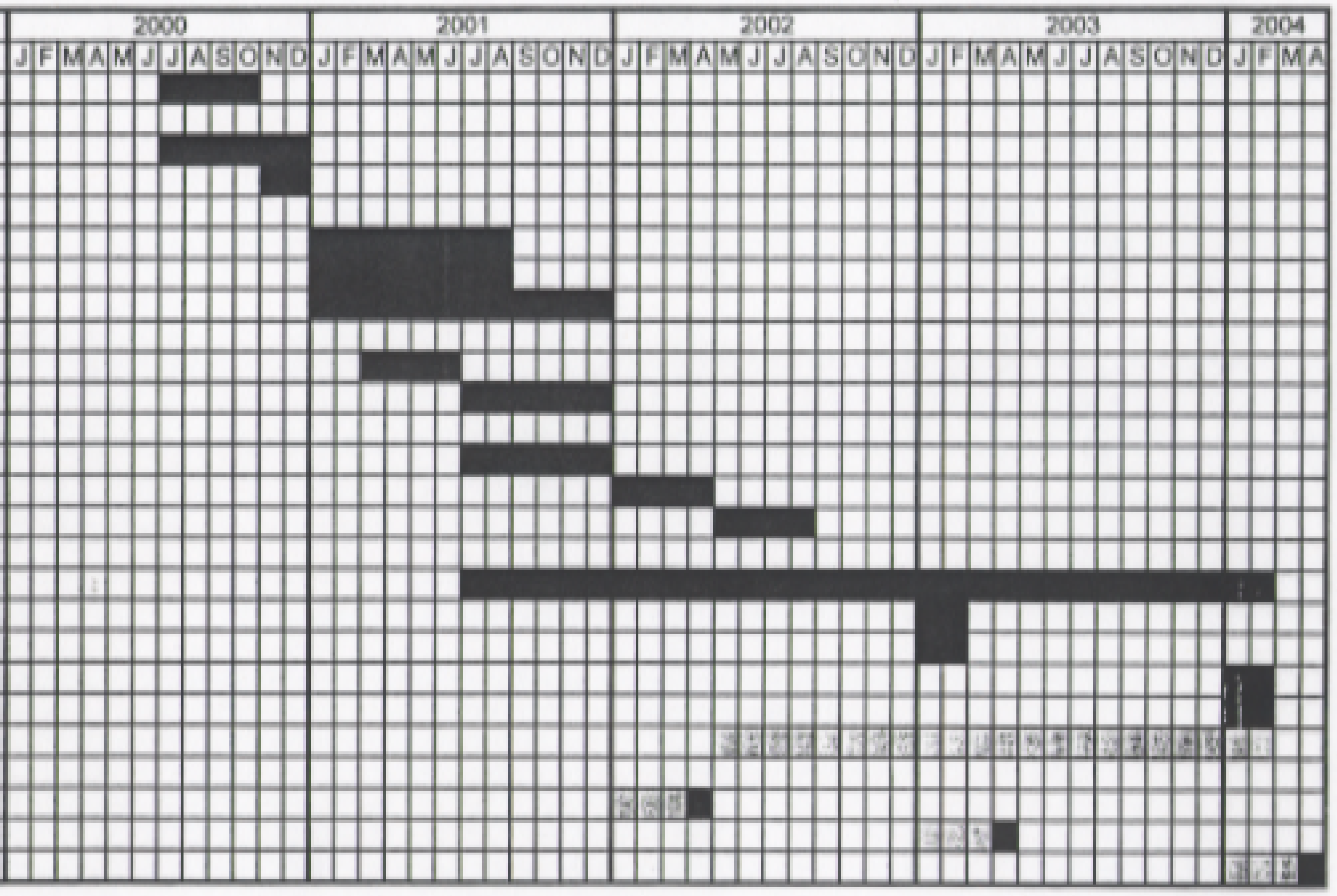
PROJECT SCHEDULE - PARTICULATE AFTERTREATMENT

task	start	end
project planning	Jul-00	Oct-00
truck and engine selection		
survey of fleet	Jul-00	Dec-00
final selection	Nov-00	Dec-00
preparation work		
engine application testing	Jan-01	Aug-01
vehicle engineering	Jan-01	Aug-01
component fabrication	Jan-01	Dec-01
durability verification		
DOC and brackets	Mar-01	Jun-01
DPF and brackets	Jul-01	Dec-01
installation of aftertreatment		
trucks with DOC (150)	Jul-01	Dec-01
trucks with DPF (30)	Jan-02	Apr-02
trucks with SCR+DPF (5)	May-02	Aug-02
testing		
backpressure checks (20-40)	Jul-01	Feb-04
DOC emissions test 1 (2)	Jan-03	Feb-03
DPF emissions test 1 (2)	Jan-03	Feb-03
DOC emissions test 2 (2)	Jan-04	Feb-04
DPF emissions test 2 (2)	Jan-04	Feb-04
SCR+DPF in-use tests (2)	May-02	Feb-04
reports		
report 1 (prepare and deliver)	Jan-02	Apr-02
report 2 (prepare and deliver)	Jan-03	Apr-03
final report (prepare and deliver)	Jan-04	Apr-04



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Mack Truck, Inc. & Renault V.I. Consent Decree Incentive Project
Ultra-low In-cylinder Emissions Engine
Scope of Work

Appendix E Project

Abstract

This is a proposal for a research project to be completed by Mack Trucks, Inc. and Renault V.I. in order to satisfy a portion of the requirements dictated in the consent decree entered between Mack Trucks, Inc./ Renault V.I. (defendants) and United States of America (plaintiff) . Specifically this research project is to satisfy a portion of paragraph 85 section c of the consent decree.

Participants

Participants of this proposed project are Mack Trucks, Inc., Renault V.I. , and several technical partners. Several technical partners which may be called upon to support this project are Robert Bosch GmbH, Diesel Technology Company, AVL, Metal Leve, Teksid, Schwitzer and Garrett.

Project Goals

All goals of this project shall be consistent with the priorities and criteria as established in paragraph 89 of the consent decree and are as follows:

1. Demonstrate that technologies to be evaluated can, or have the potential, to reduce HDDE NOx + NMHC emissions below 1.5 g/bhp-hr. NOx + NMHC levels will be driven as low as possible using those technologies and it is hoped levels significantly lower than 1.5 g/bhp-hr can be achieved.

2. Complete the project within the time constraints as dictated by the consent decree.

3. Access production viability of the technologies evaluated and potential introduction dates.

Project Description

Ultra-Low In-Cylinder Emissions Engine Phase I - Technology Description

This Phase includes the exploration of technology improvements to a common rail fuel injection system to improve the chances for successful feasibility of obtaining an engine out NOx plus NMHC level of 1.5 g/bhp-hr . Specific technology improvements are advanced rate shaping which includes precise control of boot injection duration's and pressure levels. The boot duration's and boot pressure levels will be variable over the engine operating range without dependency on engine speed / load or fixed engine hardware (See Attachment 1). This should allow us to reduce the amount of NOx generated at all operating points. Also included in this Phase is improved injection pressure control , not only peak pressure control but also average injection pressure during each injection event. The average or peak injection pressure should not be dependent on engine speed/ load or fixed hardware. Injection pressure control could be very critical to obtaining acceptable smoke/particulate levels and reduced NOx emissions, especially in the presence of exhaust gas re-circulation. Another technology improvement to the injection system is multiple injection capability such as an ability to have a pilot injection, main injection with boot pressure and a post injection all in the same injection event. Pilot injection could be used to reduce NOx at operating points where boot injection may be ineffective (light loads) and may be additive to the NOx reduction capability of boot injection at other operating points. Post injection may be beneficial in reducing particulate, NOx and NMHC in the presence of exhaust gas re-circulation.

Detailed Scope of Work

1. System Requirements

After some time for brainstorming within Mack and Renault system specifications or system requirements will be given to the supplier. System requirements are determined based on application intentions of the technology. For our case the application information which is required by the supplier is data such as engine design and layout, so that hardware of the new technology can be fitted onto the engine. Also required by the supplier is engine data such as required fuel flows, engine operating speed range and emissions goals of the engine. System requirements are to be completed no later than referenced in the project plan in Attachment 2.

2. System Design

System design will begin with computer simulation of various hardware. Several iterations of simulation will occur until a proper match of all technology hardware meets all system requirements. If all system requirements can not be met, a compromise will have to be reached between the supplier and the customer. At the completion of simulation, drawings may be necessary in order to manufacture the prototype hardware. Manufacture of the prototype hardware may take several months to more than an year , depending on suppliers availability of various components and machine tool availability. Also included in the system design, will be software writing for electronic controls of the new technology. System design is to be completed no later than as referenced in Attachment 2.

3. Concept Feasibility Study

A. Bench Testing

At the completion of all components of the new technology, the components will be procured and assembled into a system. The system will first be evaluated at the supplier on a bench test. This test is not on an engine and is for evaluating functionality of the system only. If functionality is proven to be as expected, the prototype system will be shipped to Mack Trucks for engine testing. Any desired improvements to functionality will be incorporated into the A sample components. Bench testing of the A sample components will then be done after the completion of prototype engine evaluation.

B. Engine Testing (Prototype System)

Engine testing of the prototype hardware will be of steady state nature only. Software required to do transient testing will not be available at this time in the program. Steady state engine testing will include traversing injection timing, injection pressure, boot duration, boot pressure, pilot injection and post injection effects on BsNOx, smoke and particulate. Due to the magnitude of parameters needed to be evaluated, this portion of the program may take more than one year to complete. However, this task will be completed no later than as referenced in Attachment 2.

C. Engine Testing (A Sample System)

Engine testing of the A sample system will include transient evaluations. Some or all of the steady state testing may or may not be repeated depending on the nature of functionality improvements made to the A sample system. Although all of the injection variables will have to be evaluated in a transient state, previous testing performed in the steady state will improve the efficiency of this task. Engine testing of the A sample system will be completed no later than as referenced in Attachment 2.

Ultra-Low In-Cylinder Emissions Engines Phase II

Phase II is a re-optimization of the overall combustion process to target a NOx + NMHC emissions level lower than 1.5 g/bhp-hr. NOx + NMHC levels will be driven as low as possible during this phase. Technologies included in this Phase include improved fuel spray atomization through increased injection pressures (up to 50% above current pressure capability) and possibly additional injection nozzle spray holes at smaller diameters. The increased injection pressures should reduce particulate and NOx emissions in the presence of exhaust gas recirculation. Also by reducing nozzle flow, but allowing injection pressures to increase, it will be possible to better control the ignition and burn rate therefore reducing NOx. A re-evaluation of the combustion chamber will also be required which includes investigating the effect of in-cylinder air swirl and flow, piston bowl geometry and overall compression ratio on NOx emissions. Due to increased injection pressures, and improved rate shaping as being studied in Phase I, the piston bowl geometry and air flow requirements will need re-optimized for acceptable emission control. Improved turbocharger technology will be evaluated as well. Assisted (air/oil etc.) turbochargers or staged turbochargers offer the potential for better air/fuel ratio and response throughout the engine operating range therefore potentially reducing engine out emissions.

Detailed Scope of Work

1. System Requirements

After some time for brainstorming within Mack and Renault system specifications or system requirements will be given to the supplier. System requirements are determined based on application intentions of the technology. For our case the application information which is required by the supplier is data such as engine design and layout, so that hardware of the new technology can be fitted onto the engine. Also required by the supplier is engine data such as required fuel flows, engine operating speed range and emissions goals of the engine. System requirements for Phase II should be compatible with system requirements from Phase I. Also system requirements of Phase II are to be completed no later than referenced in the project plan in Attachment 3.

2. System Design

System design will begin with computer simulation of various hardware. Several iterations of simulation will occur until a proper match of all technology hardware meets all system requirements. If all system requirements can not be met, a compromise will have to be reached between the supplier and the customer. At the completion of simulation, drawings may be necessary in order to manufacture the prototype hardware.

Manufacture of the prototype hardware may take several months to more than an year , depending on suppliers availability of various components and machine tool availability. Also included in the system design, will be software writing for electronic controls of the new technology. System design for Phase II should be compatible with system design of Phase I. System design for Phase II is to be completed no later than as referenced in Attachment 3.

3. Concept Feasibility Study

A. Bench Testing

At the completion of all components of the new technology, the components will be procured and assembled into a system. The system will first be evaluated at the supplier on a bench test. This test is not on an engine and only is for evaluating functionality of the system. If functionality is proven to be as expected, the prototype system will be shipped to Mack Trucks for engine testing. Any desired improvements to functionality will be incorporated into the A sample components. Bench testing of the A sample components will then be done after the completion of prototype engine evaluation.

B. Engine Testing (Prototype System)

Engine testing of the prototype hardware for Phase II will include steady state and transient testing. Testing will include traversing injection pressure above Phase I capability, air inlet swirl (cylinder head variations), compression ratio and bowl design (piston variations) and turbo-charging strategy . The objective of this parametric study is to reduce BSNOx+NMHC and particulate as much as possible. As in Phase I, and due to the magnitude of parameters needed to be evaluated, this portion of the program may take more than one year to complete. However, this task will be completed no later than as referenced in Attachment 3.

C. Engine Testing (A Sample System)

Engine testing of the A sample system will include any design improvements as desired and resulting from prototype bench and engine testing. Some or all of the testing may or may not be repeated depending on the nature of functionality improvements made to the A sample system. Although many of the variables may have to be evaluated with an A sample system, previous testing performed with the prototype will improve the efficiency of this task. Engine testing of the A sample system will be completed no later than as referenced in Attachment 3.

Phase I & Phase II (Merger of Technologies)

As referenced in Attachments two and three, technologies studied in Phase I and Phase II will be merged. Merging these technologies will potentially improve the benefit and possibly the effectiveness of these technologies on emissions reduction. At completion of the technology merger it will be possible to assemble a complete engine system capable of the lowest possible emissions.

1.Vehicle Evaluation

The vehicle evaluation is scheduled as referenced in attachments two and three. The vehicle evaluation will be performed on a vehicle in the Mack fleet. The vehicle evaluation is scheduled to occur over a six month period if the system is capable of operating in a vehicle environment for that length of time. Reliability issues could shorten the vehicle evaluation. The goal of the vehicle evaluation is to judge vehicle application viability and access driver acceptance on performance issues.

2. System Assessment

To conclude this program, it will be determined if this technology has met proof of concept and determine production viability. Proof of concept is simply: Did the technology do what was intended ? Production viability will evaluate such issues as time to industrialize, compatibility of technical benefits with regulatory requirements and resource requirements as compared to environmental and customer benefits.

Summary

At the completion of this project, Mack will have evaluated engine technologies which include injection systems, combustion chambers and air handling systems which would have the capability to be better than these on nearly all HDD engines produced in the world. By evaluating these advanced technologies and optimizing their interactions, the likelihood of obtaining the emissions target of less than 1.5 g/bhp-hr engine-out NOx + NMHC is greatly increased. We estimate the inventory of NOx would be reduced 1.2 tons/year for each truck at 1.5 g NOx+NMHC compared to today's highway limit of about 6.2 g NOx+NMHC or about .3 tons/year for each truck vs. a truck at 2.5 g/bhp-hr.

Ultra Low In-Cylinder Emissions Engine
Summary of Project Cost

Phase I and II

1.	Four Prototype systems for engine testing	1.10 M$
2.	Development of APCRS system (R&D/manpower).............	2.99 M$
3.	Development of ECU for APCRS control..........................	0.17 M$
4.	Application & Bench Testing	0.70 M$
5.	Engine and Related Hardware for Tests	0.05 M$
6.	Engine Testing (Test Cell/Manpower)	0.75 M$
7.	Demonstration vehicles (2 trucks for 2 years)	.29 M$
	Total......	**6.05 M$**

G05

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July 26, 2000

Subject: Mack Trucks, Inc. Incentive Program-Scope of Work

To Whom It May Concern:

Mack Trucks, Inc. is submitting our Scope of Work for our Incentive Program per Paragraph 91 of the Consent Decree. The attached documentation shows our calculations and that they meet the required emissions reductions. Please note that the time table includes the later part of the 1998 Model Year as well as all of the 2000-2001 Model years and through September 2002 Model Year. As previously mentioned in the approved submission, the engine forecasts are "the most likely sales" scenario. We have separated our sales into the EPA required 8b and 8a categories, with the 8b vehicles being those engaged in primarily on-highway, long haul operations(for example, UPS) and the 8a vehicles operating in local delivery or construction. These engines will be sold and engaged in commerce throughout the U. S.

In addition, we will include in our first quarter Compliance Representative report each year the Incentive Plan progress as required under Paragraph 105 of the Consent Decree. This progress report will include actual production volumes, types of vehicles into which the engines were installed and the NOx EURO III certification levels.

We are exercising Business Confidentiality for the attached documents.

To the best of my knowledge, after thorough investigation, I certify that the information contained in or accompanying this submission is true, accurate, and complete. I am aware that there are significant penalties for knowingly submitting false information, including the possibility of fines and imprisonment for knowing violations.

Glenn O. Shetter

Glenn O. Shetter
On Behalf of Mack Trucks, Inc.

Enclosures